Some Problems of Helicopter Operation and their Influence on Design

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H. A. MARSH, A.F.C., A.F.R.Ae.S., IN THE CHAIR.

INTRODUCTION BY THE CHAIRMAN.

It gives me very great pleasure to introduce our lecturer this afternoon, Mr. R. A. C. BRIE. I do feel that an introduction is unnecessary as most of you will either know him personally or most certainly have heard of his doings from time to time.

Mr. BRIE has been one of the foremost exponents of rotary wing flight since 1930 during which time he has never lost an opportunity of spreading the gospel of rotary wing aircraft both by word and deed and has a number of very interesting and successful flights to his credit.

He is a Founder Member of our Association and if I had my way would have been its first Chairman. He is also a Founder Member of the American Helicopter Society and of a peculiar tribe known as the " Twirley Birds," also of America.

It was my good fortune to work very closely with Mr. BRIE for some years before the war and there is no one better fitted to talk to us on the subject he has chosen.

Wing Cdr. REGINALD BRIE

Mr. Chairman, Fellow Members, and Guests:

Time flies with such rapidity that in our efforts to keep pace with the present we are somewhat apt to overlook the past. I feel it appropriate therefore in the opening stages of my lecture to recall that it is almost a quarter of a century since the first successful Autogiro flight was accomplished. On January 9th, 1923, Lt. Alejandro Gomez Spencer, a Spanish Army officer, flew the fourth full scale Autogiro to be constructed steadily across the Getafe Airfield at Madrid, and landed safely.

This unique event opened up a new chapter in the field of aeronautics, and although its significance may not have been generally appreciated at the time, it is fortunate that there was one man at least, the creator of this aircraft, who had no doubts on the matter. With infinite faith, patience and skill, he thereupon set about finding ways and means of solving the many secondary and highly complex aerodynamic and engineering problems associated with this unorthodox method of flight. How well he succeeded during the years following is apparent to all, for now the fruits of exploitation resulting from that historic achievement are about to be realised.

It appears fitting, therefore, at meetings such as these when we meet to discuss one or the other of the many aspects of rotary wing flight, that we should occasionally pause to pay tribute to such pioneering efforts; and in particular to direct our thoughts to the one man (alas, no longer with us) whose creative ability and genius not only made possible the Autogiro; but whose foresight and tenacity of purpose also so well and truly laid the foundations upon which the helicopter now so surely stands. I refer of course to Juan de la Cierva.

To the not-so-well informed, the gyroplane—of which type of freely rotating wing aircraft the Autogiro is the classic example—has had its day. On the other hand there are many well informed and expert in the art who believe that it has not yet been developed to the fullest possible extent. To that I shall revert later, but it will suffice for the moment to emphasize that no helicopter could be considered a safe, let alone a practical proposition, unless, in the event of power failure, its main rotor system was capable of autorotation. Under those conditions it is, to all intents and purposes an Autogiro. It is also significant that the most successful helicopter configurations to date embody basic gyroplane features in their design.

Although it is reasonable therefore to consider the helicopter as a logical development of the gyroplane, that does not necessarily mean to say that that development has proceeded along entirely rational lines. Whether the helicopter as such is a better type of aircraft than the gyroplane depends to a great extent on the point of view forming the basis for such an assumption. Not only is it more complex mechanically, but it is also more difficult to fly.

The " direct take-off " Autogiro clearly indicated another method by which a no-run take-off could be achieved. As a means to an end it was a step in the right direction, and its development to a practical stage was

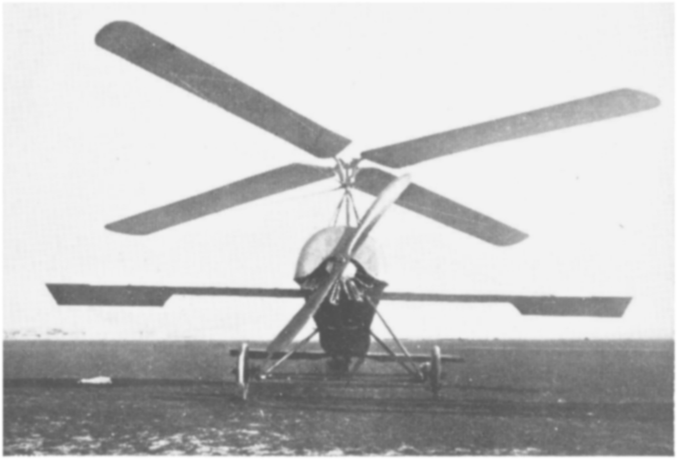

Fig. 1. *First successful Autogiro* 1923

a triumph of engineering ingenuity. Nevertheless it was an inelegant way of achieving a desirable objective; for transition from the static to airborne condition was too abrupt. The alternative method of the " towering take-off " demonstrated by the Hafner gyroplane also provided an acceptable interim solution to this particular problem.

But the real key to the optimum in ultra slow speed flying performance is undoubtedly the ability to hover in still air; and it is undisputable that the helicopter has fairly, and adequately, bridged that last remaining and all important gap in the slow speed range. That gentle levitation clear of the ground; the effortless pause motionless in space; and the thistledown-like landing on one's own shadow is slow motion flying in its purest and most elegant form; the practical attainment of which will always be associated with the name of IGOR SIKORSKY.

In attaining this optimum at one end of the performance scale, however, a penalty has had to be paid at the other, for no helicopter so far devised can be landed without power with the facility normal to the Autogiro. The manœuvres associated with an autorotational descent and landing at present call for an unusually high degree of skill in pilotage, and a consequentially unnecessary hazard to the aircraft is involved unless, and until, the disc loading can be reduced to a more reasonable value.

The too rapid loss in height resulting from this high disc loading is mainly due to the mechanical complexity, and extra structural weight involved in applying continuous power to the rotor system. It is the major part of the penalty that so far has had to be paid for the privilege of hovering. Now that the basic principles governing flight at zero speed have been established, more attention will undoubtedly be given to this problem of excessive weight; for any improvement cannot do other than

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result in corresponding beneficial advantages in other performance characteristics.

Nevertheless, and as a means of indicating that refinements in detail design do not necessarily lead to that desirable reduction in structural weight which I am convinced is the most direct, logical and advantageous

Fig. 2. *C.*19 *Mk.IV Autogiro,* 1932.

approach to improved all-round performance, I propose to present some data based on the past, the lessons of which may be of assistance in the future.

In this analysis I have selected four different types of Autogiro, and one helicopter. The basis for comparative purposes is that all are, or were, in the two-seater category; all were produced in reasonable numbers; and each incorporated some essential refinement to enhance the performance of its predecessor.

	Autogiros				Helicopter
Refinement	C.19. Mk.III	C.19. Mk. IV Clutch	C.30 Direct control	C.40 Direct take-off	R-4 Hovering
Empty Weight (lb.) ...	935	1057	1269	1350	2011
All-Up Weight (lb.)...	1400	1550	1900	1950	2540
Power	100	100	140	175	200
Rotor Diam. (Ft.) ...	35	34	37	40	38
No. of Blades ...	4	3	3	3	3
Disc Loading (lb./s.ft.)	1.5	1.7	1.76	1.5	2.24
Power Loading (lb./h.p.)	14	15.5	13.6	11.1	12.7

The first is the C.19 Mk. III Autogiro of the 1930 period. With a weight empty of 935 lbs., and an all up weight of 1,400 lbs., this machine had a four-bladed rotor; blade interbracing and suspension cables; stub wings with ailerons; a biplane type tail with elevators and rudders; and an

Fig. 3. C.40 "direct take-off" Autogiro. 1939.

engine of 100 h.p. This aircraft had the unusually low disc loading of 1.5 lb./sq. ft. but a high power loading of 14 lb./h.p.

The next selection is the C.19 Mark IV Autogiro. Although the conventional aeroplane type controls and the same power plant as in the Mk. III were retained; the main rotor now had only three blades, and the tail was of conventional appearance. The essential refinement in this case was the installation of a clutch to simplify the take-off technique which hitherto had been somewhat cumbersome. Nevertheless, despite the obvious clean-up in external appearance the empty weight had increased by 122 lbs. The all-up weight was correspondingly increased also by the round figure of 150 lbs.; the disc loading went up from 1.5 to 1.7 lb./sq. ft., and the power loading from 14 to 15.5 lb./h.p. Note particularly that the equivalent of an extra passenger was already showing itself in the shape of increased structural weight.

The third example is the well-known C.30 "direct control" type of Autogiro. Here the stub wings and all normal control surfaces have been dispensed with. The flying controls were reduced in number to the barest minimum of two—just a hanging stick type of control column and a throttle. But the empty weight had now jumped another 212 lbs.—well over the equivalent of another passenger—and the all-up weight by no less than 350 lbs. Although the rotor diameter was increased by 3 ft., the disc loading rose to 1.76 lb./sq. ft. Note also the necessity for an increase of 40 h.p. from the engine to keep the power/weight ratio within reasonable limits which, at 13.6 lb./h.p. was an improvement on the previous type. Here the essential refinement in design was a form of control the efficiency of which was quite independent of translational speed. From the general performance point of view there was no improvement on the previous type.

The fourth type is the C.40 "direct take-off" Autogiro. The penalty of undue structural weight on performance had by now become more fully appreciated, for despite a further increase of 3 ft. in the rotor diameter, and a more mechanically complicated rotor hub and transmissional system,

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the empty weight increased by only 81 lbs., and the all-up weight by a modest 50 lbs. There was a marked improvement in the disc loading at 1.5 lb./sq. ft.; and, resulting from an increase of 35 h.p. in the power requirement, the power loading was also reduced to the more reasonable value of 11.1 lb./h.p. This particular Autogiro was the direct forerunner of the single rotor helicopter, for the essential refinement in design enabled it with full load to make a no-run take-off in still air. As stated previously, this particular method of take-off had not the elegancy of the seemingly effortless take-off normal to the helicopter; but as a means to an end it was effective.

Finally, we come to the first practical type of single rotor helicopter, the well-known and familiar Sikorsky R.-4. The essential refinement in design is of course the continuous application of power to the main rotor, and the addition of a tail rotor; the combination providing the ability to hover, and a hitherto unusual degree of slow speed manœuvrability about all axes. But the price paid in additional structural weight at 661 lbs. has been a heavy one; the power loading, despite an extra 35 h.p., has increased to 12.7 lb./h.p.; and, worst feature of all, the disc loading has now gone up to the unduly high value of 2.24 lb./sq. ft., which, translated into more practical terms implies a power-off vertical rate of descent with full load in still air of 40ft./sec., or about 27 m.p.h.

A summarization of the foregoing analysis indicates that the ability to hover has thus far proved to be an expensive luxury. Expressed again in practical terms, the Sikorsky R.-4 helicopter by direct comparison with the C.40 Autogiro is actually carrying in the shape of added structural weight the equivalent of almost four extra passengers; or alternatively an additional six passengers by comparison with the earliest practical C.19 Mk. IV Autogiro. Expressing this in another way, the helicopter as we know it is roughly 1,000 lbs. heavier than the comparable gyroplane, and requires twice the power, with no corresponding improvement in the useful load, high speed, rate of climb, or basic landing performance characteristics.

Fig. 4. Sikorsky R-4 helicopter —less conventional undercarriage— hovers well clear of ground cushion effect.

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I particularly stress this structural weight aspect because I know only too well from past practical experience its influence on power and disc loading, and the undesirable effect it has on performance generally.

At the week-end meetings which used to be a feature of pre-war flying activities it was occasionally necessary to do a certain amount of juggling with removable equipment prior to staging a special demonstration, and I recall quite vividly how the removal of just one gallon of oil—the equivalent of only ten pounds in weight—from the tank of a C.30 used to make a remarkable difference to the take-off, slow flying and landing characteristics. When thus flying extra light one seemed to strike an optimum value in performance, for the aircraft was certainly much more lively to handle, with an appreciable improvement in response to a given control movement.

Thus it might well be asked whether, in fact, the development of this particular and inherent hovering characteristic of the helicopter has been worth while. To that there can be only one very positive answer, for the ability to operate a mechanical contrivance directly from or above any kind of terrain, whether it be land, water, snow, ice, or even the stickiest mud, opens up a vast and hitherto untapped field of usage. For centuries mankind has been waiting expectantly for such a miracle to happen, the potentialities of which are such as to stagger the imagination.

But the helicopter is nothing more or less than another means of transport. Its main purpose is one of convenience; to save time; and if it is to take its rightful place with other and more normally accepted means it must be able to operate with facility and safety. Additionally, of course, it must be able also to operate economically, but that particular aspect is not of immediate importance.

So in considering the problems associated with any particular form of helicopter operation, it is essential from the outset, if the objective is to have any practical value, that certain basic features of design should conform to certain definite minimum standards of requirement.

First and foremost, therefore, I consider that the most important requirement governing the basic features of design applicable to any type of helicopter intended for practical operation, is that the take-off and landing must be accomplished with greater facility, and the exercise of less skill than is possible at present. Whilst any take-off is entirely optional, the same cannot be said about any landing. Consequently I attach particular importance to the power-off autorotational characteristics, and thus to the value of disc loading, which for any given diameter of rotor is roughly proportional to the weight carried. The most direct method of reducing the disc loading to a reasonable value is by the simple expedient of getting rid of much of that excess structural weight, the extent of which I have already indicated. On this particular activity, there is undoubtedly considerable scope for ingenuity on the part of engineers who are specialists in weight control; for there is no denying that in the past there have been glaring discrepancies between design estimates and those actually achieved in practice.

So I would say, " Look after the disc loading, and the power loading will look after itself." With the amount of practical knowledge and experience now available surely it is reasonable to expect that under full load conditions, the values of power and disc loading on the helicopters of to-morrow should not exceed ten and two respectively. On the other hand, if I were asked what I considered a desirable target to aim for in regard to disc loading, I would unhesitatingly reply 1.5 lb./sq.ft.

The rotor configuration employed on any particular type of helicopter is, or should be, largely influenced by general performance requirements, and in the present state of the art the designer appears to have many alternatives at his disposal. But there are traps for the unwary, for the apparently simple theoretical layout may prove to be quite impracticable.

I suggest, however, that as long as it can be made to suffice, the employment of a single main rotor is preferable to that of a multiple system, if only from the point of view that it is a known quantity; is more simple mechanically; and easier to maintain. Although a tail rotor may offend the æsthetic taste, it is a most efficient and practical means of correcting torque, and provides a quality of control in the yawing plane for which it may prove difficult to devise a more efficient substitute.

Now almost an antique, the Sikorsky R-4 is still the only practical type of helicopter in daily use in this country. Although somewhat tricky to handle, its use in many parts of the world has been instrumental in providing a most valuable source of knowledge, and experience, of an extremely varied nature. As a result it seems likely that certain essential refinements in detail design will be an important feature of all new prototype construction of the immediate future. Consequently I propose to make only a brief reference to certain features of design, which are a matter of common interest to all concerned with helicopter operation.

From the control point of view, the principal handicap hitherto has been the necessity for manual adjustment and synchronization of collective pitch and throttle during flight; and the manual reduction of pitch in the event of engine failure. This has now been successfully overcome by purely automatic means. Whether it is preferable to use a normal throttle lever, or the more conventional helicopter collective pitch lever as an altitude control is a question for which only the actual user can provide an adequate answer. Personally, I believe that the proposed use of the main pitch lever as a means of reducing rate of descent during a genuine forced landing will be found in practice to call for such an unusual degree of timing and precision as to make the desired result somewhat difficult of achievement. For that reason I would prefer that the pitch of the main rotor should be governor controlled, and that control of the engine should be by means of a conventional throttle. Better still, I would prefer that there should be no necessity ever to have to worry about the pitch of the main rotor; that it should always be well within the autorotative range.

Pilot fatigue, especially on cross-country flights, is accentuated by residual off-set loads in the control column. These loads arise from a displacement of the C.G. of the aircraft, and their suppression by means of some simple and easily operated form of mechanical bias is most desirable.

For a considerable time I have felt that the push-pull, split wheel type of dashboard mounted control column is particularly well suited to rotor systems, and that experimentation with such an installation would be a most useful form of research activity. With the incorporation of suitable friction means to locate the fore and aft position of the rod, as well as the lateral position of the wheel, it should be possible, with correct adjustment, to fly hands-off with facility and precision.

Although I do not believe it to be an essential immediate requirement that helicopters *must* be able to fly on instruments alone, I believe it to be a matter of importance that they *should* be able to do so. There is

Fig. 5. Sikorsky R-5 equipped with pontoons.

no doubt at all about the actual efficiency of present control systems, but there is considerable room for refinement in design, and I feel the optimum will not have been reached until one can fly blind with facility.

Whilst from the control point of view the number of blades per rotor is immaterial, there are of course certain aspects of rotor blade design which have a most important influence on helicopter operation. It is not my intention to endeavour to elucidate those various parameters which form the basic features of design, for that particular field of specialist activity is the strict preserve of the aerodynamicist and the engineer. Suffice it to say that the basic requirements governing the employment of any particular rotor configuration are that it shall remain attached to the aircraft; that it shall continue to rotate during all conditions of flight; and that it shall be free from excessive vibrations.

Whether the individual blades shall be constructed of metal and wood (which is the most highly developed form of assembly to date), or alternatively whether they shall be all-wood or all-metal is not a matter about which one should attempt to be dogmatic. From the design point of view there is much to be said for all three methods. What is of major concern, however, is the behaviour in flight of the finished product, for here the operator, the maintenance engineer and the pilot all have a vital interest.

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Ease and cheapness of production; regularity of aerodynamic contour; smoothness of profile finish; standardization of unit weight; and resistance to damage, are all essential features of good blade construction.

Cheapness of production is of concern to the operator because the purchase price of the finished assembly, and expenditure on replacements, has a direct bearing on operating costs.

Standardization of unit weight, and resistance to damage, affects both the operator and aircraft engineer in that it allows an appreciable reduction in the number of spares which must be carried; and considerably reduces, in fact, it might altogether eliminate, a lot of wasteful effort and time spent in balancing and matching rotor blades.

Resistance to damage particularly includes the abrasive effects of heavy rain or hail on the leading edges, the repair of which also involves many hours of maintenance work, and much needless expense.

The regularity of aerodynamic shape, and smoothness of profile, are matters of direct concern to the pilot who is vitally interested in the absence of undue vibration, and the propulsive efficiency of the rotor system.

Theoretically the all-metal type of blade construction would appear to be the ultimate answer, although I have no doubt that the protagonists

Fig. 6. Sikorsky R-5 demonstrates its ability to lift an overload.

of the laminated compressed wood school of thought can produce very convincing evidence against such a suggestion. A considerable amount of parallel research on both methods is currently taking place, and the decision as to which is the best method must be left to time, and the user.

Ease of rotor storage is another matter of operational importance likely to call for much ingenuity in design. The question here involves reducing the overall dimensions of the aircraft for hangarage, or other reasons. Should the blades be capable of folding over the tail; or should a master blade be located aft of the pylon, and the remaining blades be removed and stored along the fuselage ? Folding has the advantage of reducing the possibility of damage in handling; but how, especially on bigger types of helicopters, is folding going to be accomplished except by mechanical means ? That in turn means more mechanical complication and additional weight. On the other hand exactly how are blades to be removed, and reassembled, without the aid of specially devised lifting equipment ?

Of course it may conceivably follow that this particular problem will only arise with the lighter types of personal helicopter with which roadability will undoubtedly be a major feature of design and utility at some future date; and that in general it will be normal for transport type helicopters to remain parked in the open with rotors extended, except for purposes of major overhaul.

Even so, however, some means will be essential to prevent undue stresses at the root end, and damage to the blades resulting from undesirable motion about the flapping hinges, due to wind action. The present normal method of restraint is by means of flexible covers on the blade tips. But the rotor hubs of bigger helicopters are likely to be at such a height above ground level as to make the blade tips unreachable other than by some kind of portable ladder, which might not be readily available when particularly required.

A possible answer to this problem might be some form of retractable anchorage eye mounted internally of the blade and towards the tip, which can be caused to retract automatically during flight, and is only open when the rotor r.p.m. fall below a certain predetermined value. The only piece of removable equipment which would then be required would be a hooked rod with a length of cord attached for connection to some convenient part of the undercarriage or fuselage.

Fig. 7. Sikorsky R-4 in hovering flight. Mr. Igor Sikorsky converses with crew.

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Precisely the same problem of blade restraint under comparable conditions will arise with any form of rigid rotor system, if ever one proves to be practical; although, as any rigidly mounted form of cantilever blade is in fact flexible in the flapping plane, it is more correct to refer to such a system as " hingeless ".

Having discussed certain features of design common to helicopters in general, the influence of which have an important effect on the operation of the aircraft, let us now consider the problem of actual helicopter operation, and the influence it is likely to have on design.

The benefit of practical knowledge gained from past operational experience is already considerable. Although mainly of a Service nature, this knowledge is equally valuable and applicable to civil activities. In fact, it is quite evident that the basic dividing line between Service and civil requirements, and its influence on design, is a fine one. Any form of difficult or normally inconvenient short distance communication; rescue in its many guises; pest control by dusting or spraying; the carriage of mails; geological surveys and oblique photography, are but a few of the many obvious examples of duties for which the helicopter is particularly well suited. So much so, in fact, that there appears to be no definable limit to the potentialities which lie ahead.

The necessity for the helicopter arises from the universal realisation that there exists a gap in the facilities provided by existing means of communication. The aeroplane suffers from the limitation of requiring specially prepared areas of considerable size to permit it to take-off and land with reasonable facility. In consequence, and to justify its use from an economic standpoint, it is forced to operate between fixed and widely separated terminal points. On the other hand, and although able to operate over routes of extremely short distances, the train and the omnibus is also equally dependent on specially prepared tracks or roads, the limitation of which have only become apparent with the ever growing realisation of the advantages arising from the use of the air as a means of saving time.

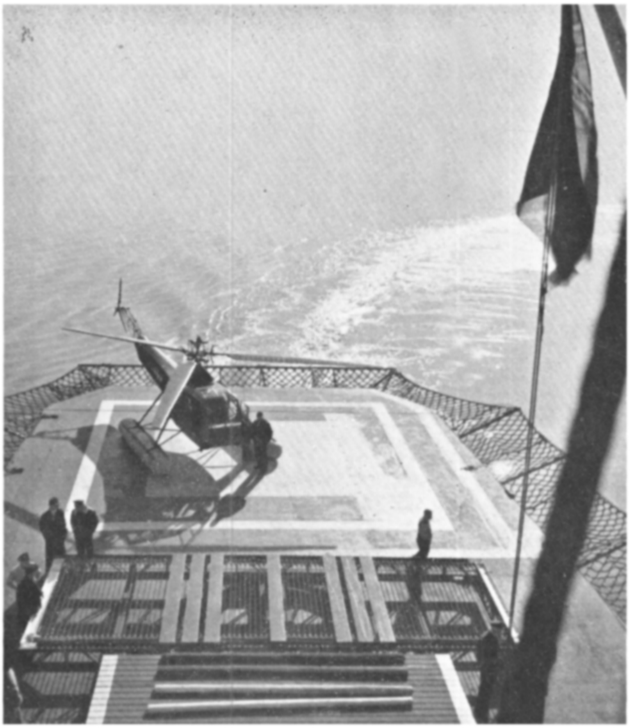

Fig. 8. *Deck landing experiments on British merchant ship " Daghestan." In foreground is experimental version of Brie patent landing and launching platform. U.S. waters,* 1943.

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The primary function of the helicopter therefore is to forge the missing link which will bridge that obvious gap in the facilities for travel at our disposal, by providing a degree of flexibility hitherto unattainable with any other means of transport. It should therefore be considered as a valuable adjunct to the aeroplane, the train, the bus, and incidentally to certain nautical activities ; for at this particular stage in its development it would be unwise to attempt to employ it in any directly competitive manner. Only as and when convincing proof is forthcoming of the helicopter's ability to render superior service should it be considered as a replacement of existing means.

To have any worthwhile utility value therefore, the helicopter must be able to provide, and carry out, some essential public service in a convenient and acceptable manner. It must be able to save time and effort. Further, it must be able to do so economically. With that object in view it must be able profitably to carry a reasonable pay load ; whether in the form of passengers or cargo depending on the nature of its employment.

Despite the limitations at present imposed by excessive structural weight on the load which a helicopter can carry for a given power, convincing proof is already to hand of its possibilities as a weight lifter under favourable conditions. By way of illustration here is a slide of the Sikorsky R-5 type (which for military purposes was originally designed as a two seater), airborne with sixteen passengers ; in actual weight the equivalent of a ton, or double its normal useful load. (Fig. 6.)

Obviously one cannot carry fare paying passengers about in such an exposed manner, but does it not appear possible that with some suitable rearrangement of the shape of the fuselage at least half that number could be carried conveniently on a journey, the duration of which might be only a matter of a few minutes? The helicopter itself is still somewhat unconventional, and thus provides a suitable motive for treating the peculiar problems of design associated with its employment in an unconventional manner.

Alternatively, and when used as an aerial crane for transporting bulky loads over short distances at low speed, where is the necessity to think in terms of streamlining, internal stowage, or even a fuselage in the accepted sense at all? A bulldozer is none the less efficient because it bears little resemblance to a lorry!

Another feature of design worthy of serious consideration relates to the undercarriage structure. Do we need conventional aeroplane type wheels and brakes on an aircraft which normally takes off and lands without any forward run, and with which even taxying is an exceptional and unnecessary manœuvre? Further, what is the necessity for massive and weight consuming shock absorbing struts? If it is considered imperative to provide some additional safeguards to accommodate the impact loads following an autorotational landing in the event of power failure, may it not be possible to devise some alternative and lighter arrangement in lieu?

One of the unique operational features of the helicopter is associated with its amazing amphibious characteristics, and this independence of terrain so enhances its general utility value as to focus attention on the provision of suitable means for providing buoyancy. To date the use of

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low pressure air inflated rubber type pontoons has proved very satisfactory, but it is suggested that here is another instance where the versatility of the helicopter stimulates thoughtful investigation, and the exercise of ingenuity on the part of designers, into the possibility of evolving a lighter and more elegant means of amphibious structure.

With shipboard operation involving flights over the open sea, pontoons or floats would obviously be impracticable for landing in rough water, although in any case some form of floatation gear must be provided for the crew. Even wheels would serve no useful purpose on the flight deck area owing to limitations of space. Hence this is an instance of special application where the conventional undercarriage might be entirely dispensed with, and the corresponding weight saved put to some more useful purpose. (Fig. 4.)

The helicopter has the ability to make any vessel with sufficient space to accommodate it an independent aircraft carrier, and experience to date has indicated that an aft location is most suitable for flight operation. When such a vessel—a cruiser or merchant ship for instance—is subject to any pronounced rolling or pitching movement, the small specially provided flight deck area is subject to an appreciable lateral and vertical displacement which can best be described as a kind of corkscrew wallowing motion. This instability, however, is of a non-periodic order, and during the few seconds available when at its minimum, a take-off or landing present no undue difficulties. A major problem with such operation is associated with providing adequate means to restrain the aircraft on the deck during the period of maximum instability, and yet enable it to take-off and land with facility whenever so desired. Manhandling under such conditions is not only dangerous but impracticable, and the ideal solution must be such as to allow the pilot to carry out all essential manœuvres of his own accord.

To this end the aircraft might be mounted on a platform of small area (say roughly half that of the rotor disc area), which is capable of being oriented into the resultant wind, thus obviating any necessity for a change in the ship's heading. (Fig. 8.) The platform itself could consist of a hollow rectangular frame within which are located a number of equally spaced flexibly tensioned cables, on which the aircraft is mounted and anchored by means of suitable hooks fitted to the lower sides of the fuselage. These hooks would be self-locking on making contact with the supporting cables, thus automatically anchoring the aircraft, and relieving the pilot of any anxiety about its stability or safety. For the take-off, and at the pilot's discretion, the hooks would be released by means of an auxiliary control.

It is conceivable that some such form of landing and take-off platform might also prove of practical use for normal commercial helicopter operation from a fixed base on land, for this conception of an undercarriageless aircraft appears to offer a positive and simple method of saving unnecessary structural weight, thus providing the means for an appreciable increase in useful load carrying capacity.

At this particular stage in the development of the rotary wing art it would be a matter of pure conjecture to attempt to predict exactly how helicopters will ultimately be used for carrying fare paying passengers ; the nature of the routes on which they will be operated ; or the minimum capacity which will prove economically acceptable to operators.

Let us be content therefore to leave the distant future to itself, and think in the more positive terms of the present and immediate future. In the Sikorsky S-51 type which is now being produced and operated in America, and models of which possibly will be in use over here later this year, we have adequate proof of the existence of a practical type of helicopter with immediate commercial possibilities. (Fig. 9.)

To many people, some of whom are not too well disposed towards the unconventional, the idea of giving serious consideration to an aircraft with a cruising speed of only 80 m.p.m. appears somewhat ridiculous, so it appears worth while recalling that the aeroplanes used on the first commercial services operated in this country, and elsewhere in 1920, had a similar cruising performance.

Now, however, it is not the intention to operate between one country and another, or over what in those somewhat distant days were comparatively long distance routes of 250 miles or so: but rather to take advantage of the inherent limitations of the aeroplane by operating on those time consuming short distance journeys between terminal airport and city centre: between one populated area and another ; and between one county and another.

For speed as such is relative, and quite meaningless in the field of air transportation unless it can be employed and used advantageously. It is not the maximum speed, but the average speed at which a journey is accomplished which matters. With helicopter operation there is no necessity to think in terms of miles an hour as such ; but rather to plan in terms of elapsed time. In other words, how long will it take to get from the point of departure to point of arrival?

It will suffice to mention that over a distance of 150 miles under still air conditions, a helicopter cruising at 80 m.p.h. and capable of operating from the centre of one city to another, is relatively as fast as an aeroplane cruising at twice that speed. Not only has the tedious road journey to and from the airport been eliminated, but from the passengers point of view there is the added convenience of avoiding an unnecessary change from one vehicle to another.

With the example given, however, there is of course no advantageous saving in time as between one method and another, so one could assume that at present it would be advisable in the case of helicopters employed on scheduled route services to limit the maximum range to a distance of 100 miles.

At the other end of the distance scale there is the fairly obvious feeder route of ten to fifteen miles between terminal airport and city centre. In effect this would amount to a special charter service for the convenience of airline passengers, and the frequency of service would depend to a great extent on the aeroplane arrivals and departures at the airport being served.

It may well be that many passengers arriving at Heathrow for instance might not necessarily desire to enter London at all, but would prefer to travel direct to their ultimate destination which still might be only a few miles distant. This kind of service would open up an entirely new field in airport traffic dispersal, in which the airport itself would be the hub, and the helicopter services would radiate to all points of the compass like the spokes of a wheel.

On the other hand, and despite the ability of the helicopter to operate from practically any small open space, it would be illogical to expect that in actual practice it will be allowed to do so indiscriminately. Owners of property and the public in general have their rights, and it appears reasonable to anticipate that in the course of time there will have to be provided carefully selected, and possibly licensed areas for helicopter operation.

The precise solution to this and many more such pertinent problems will only become apparent through practical trial and error methods; but as operation to and from the centres of towns and cities with their densely populated areas, may possibly be one of the main objectives of scheduled or unscheduled helicopter services involving the carrying of passengers and mail, there are certain other factors which also call for serious consideration.

For instance, all civil flying activities are governed by the Air Navigation Regulations, and the question might well be asked as to how helicopters can land and take-off from the centre of London for example, if one of the main provisions of these Regulations is that no aircraft may fly over a populated or built-up area except at such a height that in the event of power failure it can glide to the outskirts to land?

The object of this provision of course is for the protection of the interest of persons and property on the ground, and whilst its application in so far as helicopters are concerned might at first sight appear to be unduly restrictive, there is no doubt at all but that at this particular stage of development it would be as well to keep it in force. However optimistic

Fig. 9. The Sikorsky S.51.

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we may be about this new method of travel, let us not be blind to its limitations. Although it is common knowledge that a helicopter can land in a very restricted space, it is not so generally appreciated that the minimum area considered necessary for normal operation where obstructions are present, is of the order of 100 yards square. For such a convenient parking place to be readily available for an emergency landing in the event of power failure for instance, would be nothing more or less than sheer luck. To gamble on such an improbability would be the height of folly, and it is for that reason alone, that the employment of any single-engined helicopter for any purpose in a built-up area, calls for the most careful consideration before being permitted.

I am not opposed to roof top operation as such, for such appears inevitable at some future date; in fact the upper structure of existing terminal railway stations appears to be particularly well suited, both as to size and location, for this particular purpose. But as a precautionary measure, an essential preliminary feature of aircraft design should be the installation of two power units, so that height can be maintained on one in the event of partial power failure.

Nevertheless, there is urgent necessity for an intensive period of practical experimentation of a day-to-day nature, to enable factual data to be obtained as to the extent of the need for inter-city services; in what manner they should be operated: the type and size of helicopter best suited for this specialized purpose: and where the terminal centres are to be located.

In the meantime therefore, it is suggested that this valuable and essential information can readily be obtained with a single engined helicopter, and the use of the river Thames. Not only does this river flow through the centre of London, but it also provides an easily identifiable route from above, which can be followed with facility, even under conditions of extremely poor visibility; in fact flying need only cease when the tops of bridges were obscured. As a temporary expedient a moored flat topped barge in the Westminster or Blackfriars area would suffice for the central city terminal; incoming aircraft being confined to one bank of the river, and outgoing to the other. For later commercial operation the barge could be replaced by small specially designed platforms sited at frequent intervals along either bank; the number and location of which would naturally be dictated by experience. As a precautionary measure against the possibility of a forced landing, which would deliberately be made on the river, the aircraft would be equipped with pontoons, and some form of light anchor to guard against tidal flow.

It was as long ago as 1934 that I first conceived and officially proposed this " Riverdrome " scheme and, with the exception that it is now proposed to use helicopters instead of Autogiros, I believe that conception today to be as logical an approach to a pressing problem as it was then.

As a means to an end this scheme has the essential practical qualities of simplicity, low cost and maximum safety. For it to be tried out, some relaxation of the Air Navigation Regulations is still necessary; but I submit the use of the river does provide a reasonable loophole for special dispensation by the controlling authority.

Another feature of design which will undoubtably call for attention wherever frequent low altitude flying over populated areas is involved, is an appreciable reduction in the noise level from the engine. This probably would involve the addition of a little extra weight, but its effect on performance should be negligible, at what amounts to sea level operation.

I have already referred to the proven capacity of the helicopter as a weight lifter, and for certain requirements there seems to be no reason why any well designed helicopter should not be capable of lifting its own weight in the form of useful load. In order to take advantage of all the possiblities that the helicopter has to offer it is necessary to divorce one's mind and its associated ideas, from what might be termed " the fixed wing complex." For the time being at any rate, the helicopter is a short haul vehicle. As such its endurance, and thus the quantity of petrol it must carry need be expressed in terms of minutes only. If this assumption is correct, here is another method by which the pay load might be increased. Where and how are the additional passengers thus made possible to be accommodated under a single rotor? And in what manner will the resultant stability and trim problems be met?

It is also pertinent to enquire whether passenger seats are really necessary on such short distance journeys, or whether in fact the valuable space normally taken up by such revenue eating fittings might not be more advantageously utilized for the mutual benefit of the " aerial strap-hanger "; and operator? If course I do not expect such an unorthodox suggestion to be immediately accepted in certain quarters with the seriousness it deserves, if only on account of the fact that in this country it has not yet been possible to reproduce or even demonstrate, the vast strides being made elsewhere.

A fortunate and most agreeable characteristic of rotary wing flight, and one which all passengers will be quick to appreciate, is the apparent immunity of the aircraft from the disturbing and unpleasant effects occasioned by gusty air conditions. The rotor is in effect an efficient aerodynamic shock absorber, which absorbs and dissipates those sudden jolts, which normally cause personal discomfort, before they reach the fuselage.

Fig. 10. A typical example of an unstable platform. To facilitate shipboard operation, positive anchorage of the helicopter to the deck is essential.

If my conception of the future possibilities of helicopter travel, is as well-founded as I believe it to be, there is equally good reason to be optimistic also about developments generally in the aircraft itself, for it seems possible that the twenty and thirty passenger helicopter might be much nearer to practical fulfilment than hitherto suspected.

With the cumulative knowledge and experience now available, an intensive and accelerated programme of short-term research into the possibilities of bigger, and more efficient rotor blades might be productive of rather suprising results. It is my firm belief that only the fringe of what we may ultimately achieve with a single rotor system has as yet been touched, and I would like to see a rather more concentrated effort devoted at this stage to the engineering problems involved in the development of a 60ft. diameter rotor, rather than to multiple rotor systems of smaller diameter, but greater mechanical complexity.

To go from one extreme to the other, a rather extraordinary feature of current activity in this country is the neglect of the private owner's requirements. The reason for this apparent indifference to the sales potentialities of the personal type of helicopter is somewhat difficult to understand, for one would have thought it a comparatively simple and straightforward matter to construct a small machine capable of carrying one or two persons. Exactly when and in what matter this situation will change is problematical, but my own opinion is that the automobile industry, with its highly developed engineering methods of production, is in an excellent position to participate in the potentialities of this alternative, and most promising method of transport, whenever it chooses.

Earlier in my lecture I referred to the relative performance characteristics of the Autogiro and the helicopter, and the penalty so far paid in the achievement of hovering flight. Quite apart from the immediate necessity to tackle the problem of a reduction in structural weight, it appears likely that that desirable improvement in all-round efficiency and performance may come about through some bright new idea for achieving vertical flight without the necessity for the present complicated transmission system. The torqueless rotor which is always functioning well within the autorotative pitch range is obviously the basis of approach, but whether the rotative means for take-off and landing will be by jets, rockets, or some other at present obscure method, must be left for the future to decide.

Shorn of its technicalities, the helicopter is nothing more or less than a very precise and highly ingenious example of mechanical engineering. In discussing its limitations, and the associated problems of operation and design I have endevoured to be tolerantly critical, but constructively so. Above all I have tried to be realistic and provocative, and I thank you for coming here this afternoon to listen to me.